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CANTALOUPE POWDERY MILDEW IN THE IMPERIAL VALLEY[1]

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INTRODUCTION

The powdery mildew of cantaloupes due to *Erysiphe cichoracearum* DC. assumed epiphytotic proportions in Imperial Valley during 1925 and 1926. For the season of 1925 the actual crop loss due to the disease was estimated to have been approximately 15 per cent, and for the season of 1926 it was placed variously at 25 to 35 per cent of the total crop. As more than 27,000 acres were planted to cantaloupes in 1925 and more than 35,000 acres in 1926, these crop losses were very appreciable.

Although a few growers secured very satisfactory yields in 1926, some fields produced as few as 80 to 90 crates of cantaloupes per acre. In some instances only the first or "crown set" melons were harvested. The average yield per acre that year in Imperial Valley as a whole was approximately 110 crates per acre as compared with an average of 160 crates per acre for most of the previous seasons. The total shipments for the season were estimated to have been reduced by more than 5,000 carloads as a direct result of the mildew attack. The crop losses for the seasons of 1927, 1928, and 1929 were slight. During these years, however, there were a few early fields for which losses of 20 per cent of the crop were reported.

Actual crop losses may not be the only result of severe disease attacks. The fields of early melons are generally the most profitable of the season because of higher market prices prevailing at the time these melons are harvested and shipped. As melons from mildewed vines are of inferior quality, early shipments of poor quality fruit may adversely affect the market demand and price. The market for Imperial Valley cantaloupes in 1926 was undoubtedly affected by the poor quality of the shipments during that season. Many growers consider the reduction in quality with its consequent depressing influence upon the market to be the most serious result of the disease attacks.

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The seriousness of the disease in 1925 led the cantaloupe growers and shippers of Imperial Valley to request the aid of federal, state, and county agencies in their effects to control it. Tests of spraying and dusting materials were made by the Imperial County Farm Advisor and the Horticultural Commissioner. The State Experiment Station responded: Dr. J. T. Barrett examined conditions in the field and advised the County Agent regarding his control trials. Dr. J. T. Rosa, Associate Plant Breeder of the station in cooperation with Mr. Ivan C. Jagger, Senior Pathologist of the United States Department of Agriculture, began the work of selecting and breeding cantaloupe plants resistant to powdery mildew. The field trials of sprays and dusts showed them to be ineffectual and the results inconclusive, this being due in part to the lateness of application and in part to the use of some materials injurious to the plants treated.

The University of California Agricultural Experiment Station began the present investigation of cantaloupe powdery mildew control in Imperial Valley in June, 1926. At that time the Associated Chambers of Commerce of Imperial Valley appointed a committee to collect and expend a fund to be used in support of plant disease investigations. A general study of this disease was undertaken with particular attention to be given to control measures. Most of the field trials have been made there during the cantaloupe growing season (December to July) the work being then transferred to the Citrus Experiment Station at Riverside for the summer and fall. More than 600 field plot trials of various fungicides and methods of application have been made during the three years since 1926.

THE DISEASE AND ITS CAUSAL AGENT

Geographical Distribution and Importance.—Cucurbit powdery mildew is probably world-wide in distribution. The causal fungus (*Erysiphe cichoracearum* DC.) has long been known in European countries and its occurrence on various hosts has been reported from Asia, Africa, North and South America, Australia, and New Zealand. A recent report of the disease on squashes and pumpkins in Peru[1] states that it often assumes importance there. On the southern coast of Crimea the causal agent of tobacco mildew which was thought to be the conidial or oidium stage of the cucurbit mildew fungus, assumed epiphytotic proportions in 1926 causing a loss in one district alone of more than 250,000 dollars.[2] In the Union of South Africa, tobacco mildew is a very common leaf disease which markedly depreciates both the weight and quality of the crop.[23]

Powdery mildew on cucumbers in the United States was first reported by Humphrey[18, 19] in 1891. In 1899, Stewart[34] recorded its occurrence on field grown cucumbers in Pennsylvania. The disease had been reported on various host plants from 30 states (including California) prior to 1900. Since then it has been reported from most of the other states—in some instances causing appreciable losses in the greenhouse and field. The damage to the cantaloupe crops of Imperial Valley in 1925 and 1926 was perhaps the most severe on record because of the large acreage devoted to this crop. From Georgia, Boyd[11] in 1928, reported a 12 per cent loss. A 25 per cent loss was the maximum for any field. That year this disease was also reported as abundant in Florida but doing little damage, and as causing about 2 per cent loss in Texas.

Host Range and Specialization.—The species of powdery mildew fungus which commonly attacks cucurbits has been recorded as occurring on a wide range of other plants. Salmon[29] in his monograph, lists species belonging to 117 genera. Jaczewski[20] in his key lists 226 plant species belonging to 108 genera and 25 families as subject to attack by *Erysiphe cichoracearum* DC. A recent list[3] notes 19 economic plants upon which this species of powdery mildew fungus has been reported from various parts of the United States. Among these are the China aster, chrysanthemum, watermelon, cantaloupe, cucumber, squash, pumpkin, dahlia, sunflower, Jerusalem artichoke, okra, hop, phlox, salsify and zinnia.

In the Imperial Valley, a mildew fungus presumably belonging to this morphologic species has been observed upon all the cultivated species and varieties of cucurbits grown there with the exception of the watermelon (*Citrullus vulgaris* Schrad.) The wild gourd of this region (*Cucurbita palmata* Wats.) has been found to become slightly infected when growing in an irrigated field surrounded by other heavily infected host plants but never under other conditions. The common wild sunflower (*Helianthus annuus* L.) which grows in abundance along the ditch banks has been frequently found to be attacked by a powdery mildew fungus in early spring. This is believed to be *Erysiphe cichoracearum* since it has been identified as this species in other regions where it occurs. In the spring of 1927 leaves of hollyhock (*Althaea rosea* Cav.) growing in a dooryard in El Centro were found to be affected with a powdery mildew but as no perithecia of the fungus were present, the species could not be definitely determined. Positive identification of the fungi causing these mildews has not been possible since in every instance only the conidial stage has

been observed. As noted by Jagger[21] perithecia have not been found in Imperial Valley.

The existence of biologic strains of the various powdery mildew fungi has been rather definitely established by the work of Neger,[24, 25, 26] Salmon,[30, 31, 32] Reed,[27, 28] Blumer,[5, 6, 7] Hammarlund,[17] Bouwens,[9, 10] and others. From their results it appears that a single morphologic species causing mildew may consist of a number of specialized "biologic forms," each of these forms being restricted to a limited range of host plants. Jaczewski[20] lists 112 such "biologic forms" of *E. cichoracearum.* Only one (*Forma cucurbitacearum*) is given as occurring on species of *Cucurbita* and *Cucumis.* Reed,[28] after having made extensive culture studies of this species, concluded that the same form occurs on at least eleven species of the cucurbits belonging to seven genera. The sunflower (*Helianthus annuus* L.) was infected in 35 per cent of the trials in which conidia from the squash were sown on leaves of sunflower seedlings. Jaczewski, however, believes Reed's results with sunflower are not conclusive and need to be confirmed. It is worthy of note also that he was not able to obtain the mildew which occurs in nature on the sunflower and consequently was unable to test its capacity to infect the cucurbits.

Some evidence of the existence of such biologic strains has been noted during the course of the present work. Thus far, no instance of the spread of the disease from infected sunflowers to adjacent cantaloupe fields has been observed. Repeated cross inoculation trials made in the greenhouse and field have failed to result in infection. All attempts to infect sunflowers with the squash mildew fungus have likewise been unsuccessful. At the U. S. Cotton Field Station at Shafter, California, in August, 1927, Mammoth Russian sunflowers were found to be attacked by *Erysiphe cichoracearum.* Definite determination of the fungus species was in this case possible due to the presence of mature fruiting bodies (perithecia) on these plants. Several varieties of cucurbits growing in nearby plots were found upon careful examination to be free of the disease. These field observations and experimental results seem to indicate that the powdery mildew fungus which attacks sunflowers may be a distinct strain of *E. cichoracearum* incapable of attacking cucurbits.

Symptoms.—Powdery mildew usually appears in the early cantaloupe fields during the latter part of April. Close examination of the stems and leaves at the base or 'crown' of affected plants shows the characteristic powdery, white patches of fungus (fig. 1). These more or less circular, white spots first develop upon the shaded portions of

the main stems close to the soil and upon the undersides of the basal leaves. As they enlarge a number of the spots may coalesce covering the affected surface with a white, floury growth. The disease quickly spreads to the upper leaf surfaces, to the younger leaves and stems and to adjacent plants in the field.

The presence of the disease in a field can often be detected at some distance by the lighter green or yellowish appearance of the plants within certain rather well defined areas. Severely affected leaves lose their normal dark green color, becoming pale yellowish-green.

Fig. 1.—Characteristic powdery, white patches of powdery mildew on cantaloupe leaves. (From Exp. Sta. Cir. 308.)

If the weather is hot and dry and the soil moisture supply low, these leaves soon wilt and die, becoming dry and brittle. If, however, the weather is cool and ample soil moisture supply is maintained by frequent irrigation, such leaves may remain turgid and survive for several weeks. The loss of a large number of leaves checks the growth of the vine and exposes the maturing melons to the sun (fig. 2). These soon become sunburned and worthless. The fungus does not infect the fruit but is confined to the surfaces of the leaves and stems. However, the fruit does not mature normally and on being exposed to the sun soon softens and decays. Thus, melons from mildewed vines generally are of poor quality, the flesh lacking the desired texture, flavor and sugar content.

When weather and field conditions favor the rapid spread of the mildew, many entire fields of green, healthy vines may be reduced to rows of withered vines and rotting fruit within a few weeks after the disease appears.

Etiology.—Cantaloupe powdery mildew as it occurs in Imperial Valley is probably caused by *Erysiphe cichoracearum* DC. The absence of the perfect stage of the fungus upon any of the diseased host plants thus far observed has made positive identification of the species impossible. The perithecial stage rarely develops upon cucurbitaceous hosts. Measurements of the conidia or summer spores are of no value in determining the species of a powdery mildew. Blumer[7] concluded from the results of his work that conidial dimensions may be used to a certain extent to distinguish biologic forms or strains within collective species but not the species themselves. However, where the powdery mildew fungus on cucurbits has been found elsewhere in the

Fig. 2.—Cantaloupe vine badly affected with powdery mildew showing dead leaves and exposed, decaying melons.

United States and where, in some instances, the perfect stage has been found, the fungus has been identified as this species. The occurrence of the perfect stage of both *E. cichoracearum* and *Sphaerotheca humuli* var. *fuliginea* (Schl.) Salm. on melon leaves in Russia in 1925 has been reported.[35] The latter, however, has never been reported as attacking cucurbits in the United States.

The white, powdery spots of mildew fungus, if examined under a microscope, appear as a tangled web of much branched, interwoven fungus threads or hyphae. The threads in contact with the leaf surface develop short branches on the under side which penetrate the outer or epidermal cells of the leaf and expand to form sac-like processes known as haustoria (fig. 3). The haustoria serve as organs of attachment and as a means of absorbing nourishment from the leaf

cells. Numerous upright branches arise from the upper side of the surface hyphae. These branches develop cross walls forming chains of reproductive cells known as conidia or summer spores (fig. 4). The characteristic floury appearance of mildew spots is due to the vast number of these conidia produced. Blodgett[4] calculated that there would be 2,280,000 such spores produced per square inch of leaf surface covered with hop mildew. The chains of conidia break up, the individual cells or spores being carried by the wind to other leaves and plants where they may germinate and result in new infections if conditions are favorable. Under adverse conditions these spores soon lose their ability to germinate and cause infection.

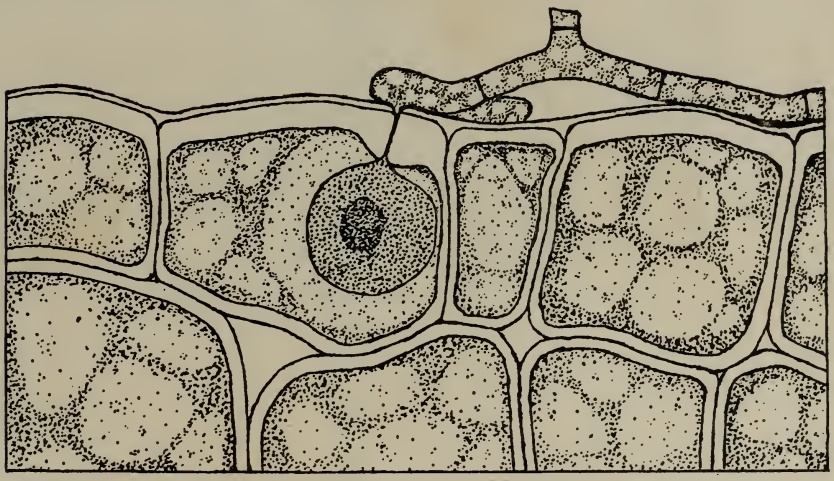

Fig. 3.—Partial cross-section of cantaloupe leaf showing fungus hypha on the surface and expanded haustorium within an epidermal cell.

As has been stated, the perithecial or winter spore stage of the life cycle of the fungus has not been found in the Imperial Valley. It has occasionally been found to develop in other regions where the disease occurs, particularly in those having cold winter climates. In the late fall upon close examination of leaves and stems of diseased plants, numerous minute, black specks may be observed. These are the perithecia or fruiting bodies of the fungus. Under the microscope they appear as globose, dark brown bodies with numerous long, thread-like appendages (fig. 5). These appendages closely resemble the fungus filaments or hyphae. Within each of the fruiting bodies are found 10 to 15 sac-like structures known as asci, each of which contains normally two, or rarely three, ascospores or winter spores (fig. 6). These winter spores are long lived and are capable of producing new infections when liberated the following spring.

Numerous observations confirm the writers' opinion that in the Imperial Valley this overwintering stage is of little or no importance in carrying the disease over from one season to the next. The fungus apparently overwinters there in the summer spore stage. Jagger[21]

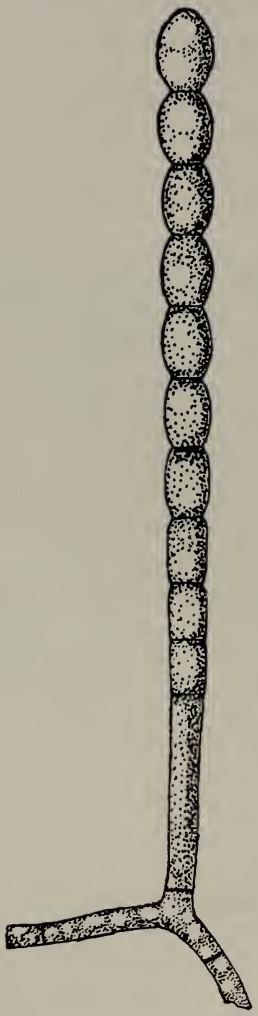

Fig. 4.—Chain of conidia or summer spores formed by division of an upright branch of a fungus filament or hypha.

reported the occurrence of mildew on volunteer melon plants there throughout the summer and fall of 1925. He also found volunteer plants with a few living leaves covered with the mildew on December 30, although frosts during December and January usually kill all

unprotected plants. These he found growing under the shelter of a hedgerow. Subsequently, the fungus in the conidial stage has been found during the fall and winter months on volunteer melon vines and on various species of cucurbits grown in the fall, winter, and

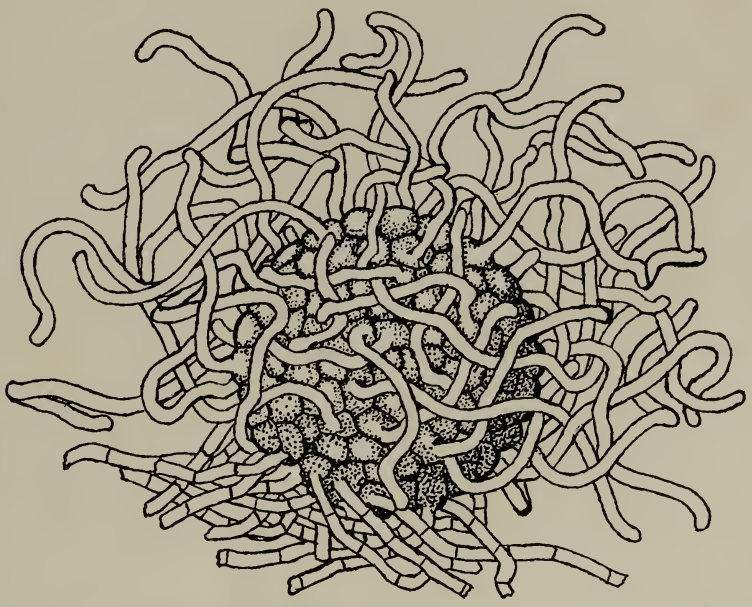

Fig. 5.—Perithecium or fruiting body of the powdery mildew fungus.

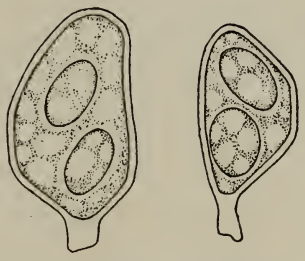

Fig. 6.—Asci which develop within a perithecium. Each ascus normally contains two ascospores or winter spores.

spring months. Susceptible host plants grow in the Imperial Valley in almost unbroken succession throughout the year. The widely distributed small patches of squash planted in the late fall and carried through the winter under the protection of brush and paper windbreaks provide a very favorable means for the overwintering of cantaloupe mildew. Diseased squash plantings are, by far, the most

important source of the early infections found in melon fields. These early infections have been repeatedly traced to adjacent or neighboring squash plantings where the disease undoubtedly overwintered and from which it spread in the direction of the prevailing winds.

CLIMATIC CONDITIONS

In the Imperial Valley.—The climate of Imperial Valley is decidedly arid. The average annual rainfall is slightly more than three inches, most of which comes during the fall and winter months. Rains during the spring and summer are normally infrequent and light, although severe storms sometimes occur during March and April. Irrigation water is used throughout the year to supply the needs of growing crops. The winters are relatively short and mild. While killing frost (temperatures of 32° F or lower) may be expected from December to February they usually are of short duration and consequently do little damage to the vegetable and other crops which grow throughout the winter. Both the maximum and minimum temperatures rise rapidly during the spring months. After the middle of April, days with maximum temperatures of 100° F or above, and minimum temperatures of 60° F or above become increasingly frequent. Strong westerly winds are of common occurrence during March, April and May. These winds bring in moisture when heavy spring rains fall in the Peninsula range of mountains to the west of Imperial Valley or in the coastal district beyond. At infrequent intervals during the spring and summer months, southeast winds may bring moisture from the Gulf of Lower California, resulting in brief periods of cloudiness or high relative humidity. In general, however, the atmosphere is extremely dry; hence, the winds usually absorb moisture and therefore have a drying effect.

Relation to the Disease.—The mild winters of this region favor the survival of the mildew through the winter months on volunteer and cultivated host plants. Although minimum temperatures of 32° F, or lower (generally considered as killing frost), may be recorded, it does not necessarily follow that all host plants will be entirely killed or even severely injured. The minimum temperature may be of only momentary duration. Plants growing in protected places, in the more frost-free areas or under the protection of "brush" may survive low temperatures of short duration with only slight injury. These brief periods of low temperature apparently are not sufficient to kill the fungus. In January, 1927, normal-appearing spots of mildew fungus

were found upon the living crowns of "brushed"[4] squash plants that had been severely injured by frost. Spore germination of mildew conidia has been reported to be favored by periods of low temperature.(13) However, rapid growth of the fungus and widespread dissemination of the disease in Imperial Valley does not occur until spring. The warmer temperatures, the periods of high relative humidity, the absence of drying winds, certain cultural practices and field conditions at this time are factors which during some cantaloupe seasons may cause the mildew to become epiphytotic.

In 1925, along with the exceptionally late rains on the coast of southern California, there was an unusual occurrence of humid, cloudy weather in the Imperial Valley. During the month of April, 1926, 1.11 inches of rainfall was recorded at Imperial and 1.99 inches recorded at Brawley as compared with .09 of an inch, the average rainfall for this month over a 20-year period at Calexico. Other weather records for Imperial Valley are lacking but those taken at Yuma, Arizona, are of interest because of the proximity of that station. There, the relative humidity for that month in 1926 was more than 20 per cent above normal, the highest on record for April. Sunshine was 87 per cent of the possible amount, the lowest on record for April. Absence of drying winds during the month was also noted. That high relative humidity favors the disease has been observed by a number of other workers. Guba(15) states that powdery mildew of cucumbers caused by *E. cichoracearum* becomes epiphytotic in the greenhouse when moisture-saturated-air conditions are not prevented by heat. Brisley(12) reporting powdery mildew of cantaloupes and watermelons in northern Arizona in 1926, stated that as long as the weather was dry there was little spread but that a few days of rainy weather permitted the spread of the disease to a marked degree. The actual precipitation of atmospheric moisture as rain or dew or the presence of free water may not be necessary for spore germination and infection of the host plant. Blumer(8) inoculated plants with *Erysiphe cichoracearum* in three different atmospheres with a relative humidity of 80 to 90, 60 to 70 and 40 to 50 per cent, respectively. High relative humidity was found to favor initial infection, the incubation period being one to two days shorter than in the drier atmosphere.

[4] Brush and paper windbreaks are used to shield the plants and blossoms from wind. Four to eight sticks of brush spaced four to six inches apart are thrust into the ground. The tops of the sticks are inclined forward over the plants. Two double sheets of newspaper are then placed against the brush sticks. Four to eight more sticks are then placed behind, and soil is hoed over the base of the paper to keep it in place.

During the seasons of 1926 and 1927 the official weather records kept at Phoenix, Yuma, Mexicali, Calexico, Imperial and Brawley over a period of years were assembled, tabulated and compared. An attempt was made to find evidence of a possible correlation between such factors as temperature, rainfall, relative humidity or number of cloudy days, and the occurrence and prevalence of cantaloupe powdery mildew in a given season. The only evidence found has been noted. These records were incomplete in some cases and, at best, were deficient in several respects. No information was available as to the duration of certain conditions of temperature or humidity. Believing such data to be of particular value in a study of the disease or of sulfur injury, thermohygrograph records were kept in the experimental fields during 1927 and 1928 from March 15 to June 10. The first evidence of cantaloupe mildew in commercial fields in previous years had been reported about April 15.

CONTROL EXPERIMENTS IN 1926

Control experiments were started in Imperial Valley late in June, 1926, near the close of the cantaloupe season. As the disease had been widespread some difficulty was experienced in locating late-planted untreated fields in which mildew was not then well distributed and prevalent. One acre in each of two fields southwest of El Centro was selected and subdivided into $\frac{1}{200}$ acre test plots, with frequent check plots and guard rows. The same series of control treatments were applied to the test plots in both fields. The various materials were applied from June 24 to 26 inclusive, each plot receiving only one application. Mildew was present in both fields and had become well established in the more mature one in which the first melons were then being harvested. Hot, dry weather prevailed during the course of the experiments, the daily maximum temperatures being over 100° F.

Dusting Experiments.—The following materials were applied as dusts, each at rates of 20, 40, 60, 80, and 100 pounds per acre.

Hydrated lime.
Gypsum
Copper carbonate +talc (15–85 mixture).
Copper sulfate (monohydrated) + lime (19–81 mixture).
Sublimed sulfur (35 per cent amorphous).
Sublimed sulfur (28 per cent amorphous).
Ground sulfur.
Black gas sulfur (92 to 95 per cent sulfur).
Sulphogerm (16 to 24 per cent sulfur).

Sublimed sulfurs + lime (50–50 mixture).
Sublimed sulfurs + gypsum (50–50 mixture).
Ground sulfur + lime (50–50 mixture).
Ground sulfur + gypsum (50–50 mixture).
Ground sulfur + whiting (50–50 mixture).
Ground sulfur + whiting (25–75 mixture).
Sulphogerm + lime (50–50 mixture).

In addition to the mixtures listed above ground sulfur and the two grades of sublimed sulfur were mixed with hydrated lime in the proportions 40–60, 30–70, 20–80, and 10–90 and applied to plots in quantities equivalent to a 20-pound per acre application of the sulfur in each case. Dustings were made with a crank type hand duster.

Applications of Sulfur to Surface of Soil.—Ground sulfur, two grades of sublimed sulfur, and black gas sulfur, were also applied to the soil surface of a series of plots in quantities of 20, 40, 60, 80 and 100 pounds per acre. These quantities were distributed in small piles in a semicircle six to twelve inches from the crown of each hill in the plot on the side opposite the irrigation furrow.

Spraying Experiments.—The following liquid sprays were applied with small hand sprayers to a series of test plots each in quantities of 50 gallons per acre: a 2 per cent emulsion of highly refined oil such as was extensively used in the spraying of citrus trees in southern California; potassium sulfide, 3 ounces in 10 gallons of water; Oregon cold-mix lime and sulfur; bordeaux mixture 3–4–50; bordeaux 3–6–50; bordeaux 4–4–50; sodium chloride, 2 per cent solution; sodium chloride, 4 per cent solution.

Results.—Although the plots were kept under close observation until the fields were abandoned, no definite evidence of the control value of the various treatments could be obtained for several reasons. In the older field the disease had progressed to such an extent by the time the treatments were applied that effective control was not possible. In the other field the development and spread of mildew was apparently checked by the hot, dry weather prevailing at the time. At the time this field was abandoned very little disease could be found in either the treated or the untreated sections. Where sprays or dusts containing sulfur were applied such severe injury to the vines resulted that the amount of damage done exceeded that of the disease itself.

The first evidence of sulfur injury on plots which had been dusted with sulfur, or with sulfur-containing mixtures, began to appear within five days after the material had been applied. The blades and petioles of the more mature leaves, which are most susceptible to sulfur injury, wilted, turned brown and died, becoming dry and very

brittle. Where heavy applications of sulfur were made, even the young leaves were injured and later died. The plot on the right in figure 7 was dusted with sublimed sulfur (28 per cent amorphous) at the rate of 100 pounds per acre on June 24 and photographed July 1. The plot at the left was an untreated check. The lighter applications of sulfur caused proportionately less injury but even the smallest quantity used in these trials was markedly injurious to the vines. In these experiments all the grades of sulfur used were equally injurious as may be judged by comparison of the treated plots shown in figures 7 and 8.

Lime or gypsum alone had neither fungicidal value nor injurious effect on the plants. In mixtures with sulfur they did not appreciably reduce its injurious effect, serving only as inert carriers. The copper carbonate-talc and monohydrated copper sulfate-lime dusts were non-injurious. Very slight damage to the vines resulted where sulfur had been put in piles on the surface of the soil. Of the liquid sprays used only the potassium sulfide solution and the bordeaux mixtures did not severely injure the plants sprayed.

EXPERIMENTS IN 1927

The mildew control experiments were continued early in the spring of 1927 in a field northwest of Imperial. From the previous season's results with sulfur dusts it seemed desirable to determine whether or not smaller quantities applied early in the spring or at intervals during the growing season might prove effective in controlling mildew and yet be non-injurious to the plants treated. In the case of the liquid spray and the soil applications as well, it seemed likely that smaller quantities of the materials applied earlier or perhaps at some critical period in the development of the disease might result in more satisfactory control than would larger amounts applied later. The 1927 field plot trials were planned with the intention of determining the influence of the rate and time of application of the various materials.

Five acres of the field were divided into series of $\frac{1}{50}$ acre plots with ample check plots and guard rows. The first treatments were applied late in March, shortly after the paper caps were removed, the vines then having runners about a foot long. The last treatments were applied early in June, the plots being kept under observation until June 20, when the harvest was almost completed and the field ready to be abandoned. Records of temperature and humidity in the field were obtained by means of a recording thermohygrograph placed in a shelter set on the south slope of a cantaloupe bed between and

Fig. 7.—Plot on right dusted with sublimed sulfur at the rate of 100 pounds per acre on June 24; plot on left, untreated check. Photographed July 1.

Fig. 8.—Plot on right dusted with ground sulfur at the rate of 100 pounds per acre on June 24; plot on left, untreated check. Photographed July 1.

on a level with two hills of plants (fig. 9). The readings were checked frequently, the accuracy of the hygrograph being determined by the use of a sling psychrometer and the U. S. Weather Bureau psychrometric tables. Strong westerly winds occurred often during March, April, and May.

Dusting Experiments.—A part of the series of $\frac{1}{50}$ acre plots was dusted with each of the following materials: Kolodust; sublimed sulfur (35 per cent amorphous); black gas sulfur; ground sulfur; monohydrated copper sulfate-lime; and dry bordeaux mixture (22 per cent Cu). In each series a single material was applied to separate

Fig. 9.—Recording thermohygrograph kept in shelter on a cantaloupe bed to obtain continuous records of temperature and humidity conditions at ground level in the field.

plots in total quantities of 5, 10, 15 and 20 pounds per acre applied in one, two and three applications as shown in table 1: the first, March 26; the second, April 23; and the third, May 21. Thus a given material was used on 12 separate plots. The extent of injury to the plants is also given.

An arbitrary numerical system of evaluating the injurious effects of the various treatments was adopted, using the numbers 1 to 12 inclusive. Thus, the injury resulting from the applications to individual plots was graded in accordance with this system; 1 to 3 representing slight injury, 4 to 6 moderate injury, 7 to 9 severe, and 10 to 12 very severe injury to the plants. Any treatment which injured the plants to a degree greater than 4 on this scale was considered too toxic to be recommended for general use.

To obtain a uniform distribution of such small quantities of fungicidal material as were applied it was found necessary to mix them with a relatively large amount of an inert carrier. Mixtures were prepared using 15 per cent of the fungicide and 85 per cent diatomaceous earth (kieselguhr). Dustings were made with a crank type hand duster.

Mildew did not develop until June 13 and then only in two small areas in the northeast corner of the field, beyond which it did not spread to any extent before the field was abandoned. The relative control value of the various treatments applied could not be determined owing to the late appearance of the disease and its subsequent failure to spread.

TABLE 1

Treatments Applied to Dusted Plots and Extent of Injury to Plants Where Sulfurs Were Applied

Plot	Quantity of fungicide applied, pounds per acre			Sulfur injury*
	March 26	April 23	May 21	
A 1	5.0	.....	.....	1
A 2	10.0	.....	.....	1
A 3	15.0	.....	.....	2
A 4	20.0	.....	.....	3
B 1	2.5	2.5	.....	4
B 2	5.0	5.0	.....	5
B 3	7.5	7.5	.....	6
B 4	10.0	10.0	.....	7
C 1	1.6	1.6	1.6	6
C 2	3.3	3.3	3.3	7
C 3	5.0	5.0	5.0	8
C 4	6.6	6.6	6.6	9

*Sulfur injury gradation figures 1 to 3 represent slight injury to foliage of treated plants; 4 to 6, moderate injury; 7 to 9 severe injury; and 10 to 12 very severe injury. Treatments causing injury greater than 4 on this scale were considered too toxic for general use.

The monohydrated copper sulfate-lime and the dry bordeaux mixture dusts did not, in any instance, injure the plants to which they were applied. Toxicity of the sulfur dusts varied only with the time and quantity applied, all grades of sulfur used being equally injurious. The figures given for sulfur injury in table 1, therefore, apply equally to the four kinds of sulfur used in the dusting experiments. Sulfur injury was first noted during the first week in May. During the preceding two weeks the daily temperatures as recorded in the field ranged from 60° to 103° F. Final notes were taken June 4, two weeks after the last dusting.

Applications of Sulfur to Surface of Soil.—Three kinds of sulfur, sublimed, black gas, and ground, each in quantities of 30, 60, 90 and 120 pounds per acre were applied to the soil surface of series of plots in one, two and three applications. Two methods of distributing the sulfurs were used. On one set of plots in each series the applications were distributed in small piles as in the 1926 experiments, while on another set like quantities were sifted in semicircles around each hill on the side opposite the irrigation furrow. The three applications were placed approximately 12, 24 and 36 inches respectively from the crown of the hills and were made on April 1, April 29 and May 27. Table 2 shows the dates of application and the quantities per acre used for each material employed. A similar set of plots was used where the same quantities of various sulfurs were spread in circles about the hills. The degree of injury resulting from applications made to the various plots is also shown.

TABLE 2

APPLICATIONS OF SULFURS TO SOIL SURFACE OF PLOTS AND RESULTANT INJURY

Plot	Quantity of Sulfur applied, pounds per acre			Sulfur injury*	
	April 1	April 29	May 27	Sulfur in piles	Sulfur scattered
A 1	30	....	....	2	2
A 2	60	....	....	4	4
A 3	90	....	....	5	6
A 4	120	....	....	7	8
B 1	15	15	....	2	3
B 2	30	30	....	4	5
B 3	45	45	....	6	7
B 4	60	60	....	8	9
C 1	10	10	10	2	3
C 2	20	20	20	4	5
C 3	30	30	30	6	7
C 4	40	40	40	8	9

*Expressed on a numerical basis, 1 to 3 representing slight sulfur injury, 4 to 6 moderate, 7 to 9 severe, and 10 to 12 very severe injury.

The applications of sulfur to the soil surface of plots in most cases proved markedly injurious to the cantaloupe plants. The degree of injury resulting from the various applications as shown in table 2 varied with the quantity applied, and method of application, and only to a slight extent with the time they were made. The same quantities of the four grades of sulfur applied proved equally injurious if applied at the same time and in the same manner. The strong winds which occurred frequently during March, April, and May of this season probably account for the difference in the results of these

trials as compared with those of the previous year. These winds probably lifted some of the sulfur from the soil and deposited it on the stems and leaves of the plants. Spreading the sulfur on the soil would expose more of it to the wind than if the same quantity were concentrated in small piles; hence, more of it would be carried to the plants. This seems to have been the case in these experiments as more injury resulted where the sulfur was sifted in circles around the hills than where a like quantity of the same sulfur was applied in small piles. Differences in size or weight of the particles of the sulfurs used evidently were not important factors in these trials. Notes of the relative degree of injury or so-called "sulfur burning" were made two weeks from the date of the last application.

Spraying Experiments.—Individual plots were sprayed one, two, three, four and five times with each of the following: colloidal sulfur, 21.5 ounces in 50 gallons of water; precipitated sulfur, 12.8 ounces in 10 gallons of water; sulfur-caustic soda-resin (sar sclution), 1 gallon stock solution to 50 gallons of water; oil emulsion 2 per cent; bordeaux 4–4–50; bordeaux 2–4–50; iron sulfide, 2 gallons of stock solution in 20 gallons of water; potassium sulfide, 3 ounces in 10 gallons of water; Oregon cold-mix lime and sulfur; concentrated waste sulfite liquor, 2 per cent in water; black gas sulfur, 12.8 ounces in 10 gallons of water; ammoniacal copper carbonate, 6 ounces copper carbonate and 3 pints ammonia in 50 gallons of water; and copper acetate, 6 ounces in 50 gallons of water. The spray treatments were begun on April 3 and the successive applications were put on at two-week intervals thereafter until June 3. Application of 100 gallons per acre were made. In table 3 the schedule of sprayings is shown and the relative degree of injury caused by the successive applications of the toxic ones with the exception of ammoniacal copper carbonate.

TABLE 3

Schedule of Spray Applications and Degree of Injury Resulting Where Toxic Sprays Were Applied

Plot	Quantity of sprays applied, gallons per acre					Degree of Injury*
	April 8	April 22	May 6	May 20	June 3	
A 1	100	.....	.....	.....	.....	3
A 2	100	100	.....	.....	.....	5
A 3	100	100	100	.....	.....	7
A 4	100	100	100	100	.....	9
A 5	100	100	100	100	100	11

*Expressed on a numerical basis as in tables 1 and 2.

The following sprays did not, in any instance, injure the plants to which they were applied: potassium sulfide, bordeaux mixture 4–4–50, bordeaux 2–4–50, copper acetate and sulfite waste liquor. Ammoniacal copper carbonate caused moderate injury, producing small, dead areas in the leaves of the sprayed plants. All of the other sprays used injured the plants treated to the extent noted in table 3. The injury to the plants sprayed with oil was similar to that observed by Guba[15] on cucumber plants sprayed with this material in a greenhouse in Massachusetts. In hot weather, a few days after plants have been sprayed with this oil, the leaves begin to turn yellow and appear oil-soaked or semi-transparent. They soon wilt, turn brown and become crisp. In cooler weather the injury makes its appearance more slowly. Mildew was first observed in this field on these plants which had previously been sprayed with oil. No evidence was found that the previous treatments gave these plants protection from infection.

Field Experiments at Riverside.—In July the work was transferred to the Citrus Experiment Station at Riverside where it was continued in the field and greenhouse. Seed collected from mildewed sunflower plants in Imperial Valley was sown in the field and greenhouse at Riverside. Although repeated attempts were made to inoculate the plants grown from this seed with the cantaloupe mildew fungus, no infection resulted. Attempts to inoculate a squash, cantaloupe, cucumber, casaba, and pumpkin vines with the spores taken from infected sunflower leaves also failed. Plants of these varieties inoculated at the same time with mildew spores from cantaloupe leaves showed positive evidence of infection after eight days. The disease developed very slowly thereafter.

It had often been observed in the field and found recorded in the literature that plants growing in shade were more severely attacked by powdery mildew than were those exposed to direct sunlight. To test the effect of shading, muslin shelters were placed over individual hills of cantaloupes, casabas, Hubbard and Italian squashes as shown in figure 10. The plants were then inoculated with mildew fungus. The conditions of reduced light intensity, higher humidity and lower temperature within the shelters favored rapid growth of the fungus. Within two weeks all leaves of these plants showed numerous, sporulating mildew spots. Leaves of similar plants in the open had very few, if any, spots. Healthy, potted sunflower plants grown from the seed collected in Imperial Valley were brought from the greenhouse and placed under these shelters. Although, presumably, optimum

conditions for infection with mildew prevailed, these plants remained healthy.

Plants of several varieties of cucurbits growing in the open field were sprayed with different strengths of both soda (sodium carbonate) and waste sulfite liquor. Results with these materials were negative with respect to control of the disease. Dusting of several varieties of squash with different commercial grades of sulfur at two-week intervals resulted in satisfactory control of mildew with little or no injury to the plants treated.

Fig. 10.—Muslin shelters placed over plants to note effect of shade upon development of mildew.

EXPERIMENTS IN 1928

For the 1928 experiments approximately five acres of an early-planted cantaloupe field in the Meloland district were used. The size of individual plots was enlarged to $\frac{1}{25}$ acre. As the previous season's field trials had given no information as to the relative value of the various treatments in controlling the disease because of the late appearance of mildew in the field, it seemed desirable to repeat at least some of them. Of the sprays and dusts used in former experiments, those which had severely injured the plants were eliminated from the 1928 trials, except in one instance where sulfur dust was used for a comparison of results. The sublimed and black gas sulfur

applications on the soil were repeated in comparison with two other forms of commercial sulfur applied in the same way. In the literature on powdery mildews references were found indicating that a relationship exists between fertility of the soil and susceptibility of the plants to disease, particularly with respect to the available supply of nitrogen, phosphorus, and potash in the soil. A series of fertilizer trials was therefore included. The fertilizers were applied in December after the beds were thrown up but before the seed was planted. The dust, spray and soil applications were made at four-week intervals from April until June. Temperature and humidity records were kept in the field as during the previous season.

Dusting experiments.—A series of $\frac{1}{25}$ acre plots was dusted three times at four-week intervals, beginning April 10, with the following materials: dry bordeaux mixture (22 per cent Cu); dry bordeaux (12 per cent Cu); monohydrated copper sulfate-lime; barium tetrasulfide; sublimed sulfur (35 per cent amorphous); and diatomaceous earth (kieselguhr). Four plots were used for each of the materials, these receiving applications of 5, 10, 15 and 20 pounds per acre, respectively, at each dusting. Thus, after the last application, these four plots had been dusted with quantities of fungicide equivalent to 15, 30, 45 and 60 pounds per acre. To secure uniform distribution where small amounts of fungicide were to be applied, it was mixed with an equal amount of diatomaceous earth, an inert carrier.

Diatomaceous earth applied as a dust was neither fungicidal nor injurious to the plants treated. The possible value of either barium tetrasulfide or sublimed sulfur dusts as fungicides was obscured by the amount of injury to the plants which resulted from their application. The first dustings with these materials in quantities of 5, 10, 15, and 20 pounds per acre caused approximately the same degree of injury as was noted for the first sulfur dust applications of these quantities during the previous season. The amount of damage to the plants increased markedly with the second and third dustings. The final notes taken give the degrees of injury caused by three applications of these quantities of sublimed sulfur and barium tetrasulfide as 7, 8, 9, and 10, respectively, for the different quantities used. The dry bordeaux mixture and copper-lime dusts, though non-injurious, gave slight evidence of control. However, although the disease was present it did not develop uniformly in the untreated check plots in this portion of the field.

Application of Sulfur to Surface of Soil.—Four grades of sulfur were distributed in small piles on the soil of a series of plots. The

grades of sulfur used included sublimed, coarse ground, black gas and a sulfur mixed with an oxidizing agent, the latter made in accordance with the patent of Lee and Martin[22] and supplied by the San Francisco Sulphur Company, their licensed agent for its manufacture. Each grade was applied to separate plots in quantities of 10, 20, 30, and 40 pounds per acre per application. Three applications were made: the first, April 5; the second, four weeks later; and the third, eight weeks later. For the three applications the total amounts of a given sulfur which had been applied to the plots was equivalent to 30, 60, 90, and 120 pounds per acre. The size of the individual particles of the ground sulfur was approximately the same as that of ordinary coarse sand.

The first mildew was discovered in the field on April 30 in the plot on which sublimed sulfur at the rate of 10 pounds per acre had been distributed in small piles on April 5. Plants of the one hill found at that time were pulled up and buried on the spot by the field foreman. After the prompt destruction of the first diseased plant found there, mildew developed upon some adjoining plants in the row but did not become generally distributed. Very slight sulfur injury was noted in any case, even where the larger amounts had been applied. This was probably due to the presence of a field packing shed at the western end of these plots, the shed serving as an effective windbreak. Other diseased plants were then present in the south end of the field. From these, mildew gradually spread eastward with the wind across the sprayed plots and thence into some of those which had been dusted. Mosaic was generally prevalent in the field, over 75 per cent of the plants being severely attacked by this disease. Crop loss from mildew alone was approximately 20 per cent. The field was abandoned after scarcely more than 80 crates of melons per acre had been harvested. Most of those were probably first or "crown set" melons. The field was irrigated frequently after April 15.

Spraying Experiments.—Plots were sprayed one, two, and three times at four-week intervals beginning April 9 with each of the following: bordeaux 4–4–50; bordeaux 3–3–50; copper acetate; ammoniacal copper carbonate; potassium sulfide, 1 ounce in 3 gallons of water; ammonium sulfide, 3⅓ liquid ounces in 10 gallons of water; barium tetrasulfide, 6.4 ounces in 10 gallons of water; sodium carbonate, 33 per cent solution; and waste sulfite liquor, 2 per cent. These were applied in quantities of 100 gallons per acre. None of the sprays applied, except the bordeaux mixtures, showed any evidence of controlling the disease. Three applications of the 3–3–50

and the 4–4–50 mixtures gave the best results. Even these, however, did not wholly eradicate the disease or prevent subsequent infection of the treated plants. Growth of the plants following the spray applications and the inability to cover all the plant surfaces with spray, especially the lower surfaces of the leaves, probably account for this. Barium tetrasulfide applied as a spray was decidedly toxic to the plant foliage.

Fertilizer Applications.—Sixteen $\frac{1}{25}$ acre plots were used for a duplicated series of fertilizer trials. Potassium sulfate (50 per cent K_2O), ammonium sulfate (20 per cent N), and triple superphosphate (46 per cent P_2O_5) alone and in various combinations with the others were applied in quantities and in proportions that would be used if 750 pounds of a 4–8–5 mixture were applied per acre. Sublimed sulfur (125 pounds per acre) was also applied to duplicate plots. These were distributed along the bottom of a furrow about four inches deep on the south slope of the bed and at the approximate height of the planting line. Immediately following the distribution of the fertilizers the four-inch furrow was filled in and several days later the field was planted. Results of the fertilizer trials were negative, the quantities of the various materials applied having no apparent influence on the susceptibility or resistance of the plants to powdery mildew.

Variety Planting.—A planting of squash, cucumbers, casabas, pumpkins, and cantaloupe selections was made in a field near Heber. Most of the latter were progeny of field selections made in 1926 and grown at Riverside in the summer and fall of 1927. The field in which the cucurbit varieties and cantaloupe selections were grown remained free of mildew throughout the season.

Temperature and Humidity Records.—As has been mentioned, in 1927 mildew did not appear in the experimental field until June 13 and caused no crop loss thereafter. In 1928, it was first discovered in the experimental plots on April 30 and that year caused a loss of approximately 20 per cent of the crop in that field. Comparison of the temperature records kept in these fields showed very slight differences in the number of hours of temperature above 70° F recorded during the period from March 15 to June 10. The variations in the records of the hours of temperature above 90° F are shown in figure 11. It will be noted that there were fewer hours of high temperature recorded from March 15 to May 13 in 1928 than in the preceding year. This, together with the greater number of hours of high relative humidity (above 70 per cent) after April 14 as shown in figure

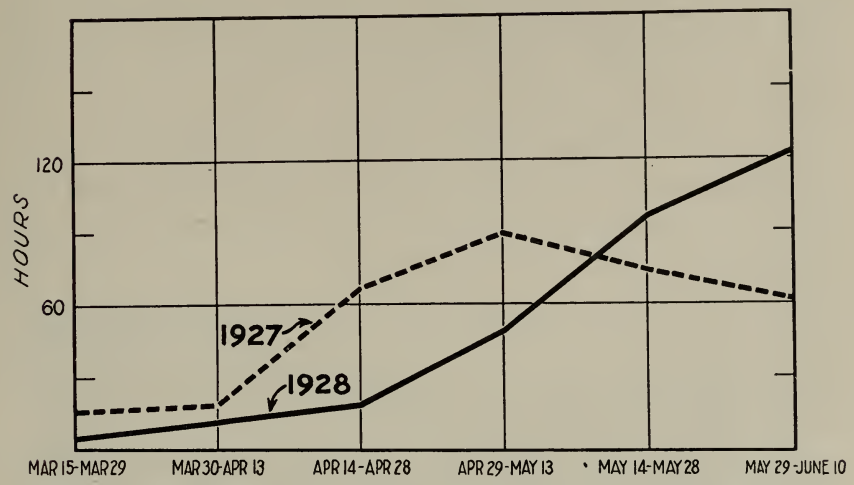

Fig. 11.—Number of hours of temperature above 90° F recorded in the 1927 and 1928 experimental fields during the period from March 15 to June 10. It will be noted that fewer hours of high temperature were recorded from March 15 to May 13 in 1928 than in the preceding year.

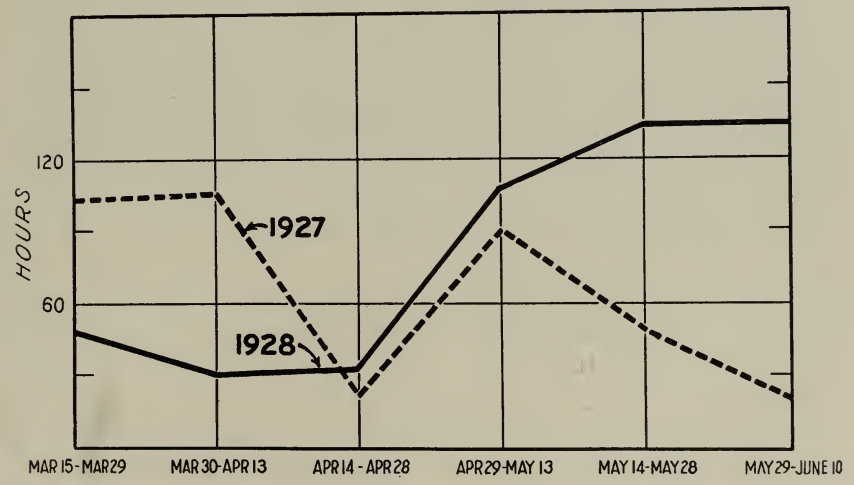

Fig. 12.—Hours of relative humidity above 70 per cent recorded in the 1927 and 1928 experimental fields during the period from March 15 to June 10. Fewer hours of high relative humidity were recorded during the first month of the period in 1928 but thereafter a greater number were recorded than in 1927.

12 probably favored the initial development and subsequent spread of the disease in 1928. The number of hours of high relative humidity from May 14 to June 10 of that year greatly exceeded that for the same period in 1927. The frequent irrigations of the 1928 field during that period perhaps account, to a certain extent, for this difference. Although the number of hours of relative humidity above 70 per cent from March 15 to April 13 was greater in 1927 than in 1928 there was little difference in the hours of temperature above 90° F during the same periods. Minimum temperatures during this part of the growing season are generally below 60° F which, from field observations, appear to be unfavorable for the rapid growth and spread of cantaloupe powdery mildew. Of the two factors, temperature and humidity, the latter is probably the more important but this can be determined only after records of several seasons have been obtained and compared.

Field Experiments at Riverside.—During the summer, further trials of sulfur, dry bordeaux, and dry bordeaux-arsenate dusts for the control of mildew were made on plots of Persian melons in the Moreno Valley of Riverside County. In general the results obtained were similar to those secured from comparable dustings applied in the Imperial Valley. Seed of one plant which exhibited marked resistance to sulfur injury was harvested and saved for further trial.

EXPERIMENTS IN 1929

In two fields, one in the Mount Signal district, the other west of Brawley, ¼-acre plots were dusted three times at two-week intervals with the following materials: dry bordeaux (22 per cent Cu), dry bordeaux (12 per cent Cu), and copper stearate (9 per cent Cu). These were applied with a crank-type hand duster in quantities equivalent to 3 pounds of copper per acre. In both fields, mildew was just beginning to develop, having spread from nearby infected squash plantings. It spread rapidly causing a loss of approximately 25 per cent of the crops in those fields. The first dusting was made on May 5.

None of the copper dust applications gave any evidence of controlling mildew. New infections appeared upon leaves heavily coated with these dusts. These spots developed normally. Presence of the dry copper dusts apparently did not prevent germination of the mildew spores, infection of the leaves, or subsequent growth of the fungus. Humidity of the air, however, was sufficiently high to be favorable for the germination of spores and infection of the plants.

A planting of cucurbit varieties and selections in a field in the Westmoreland district remained free of mildew throughout the season. This planting was heavily sulfured on June 1 and seed melons were selected from the more resistant plants a week later.

DISCUSSION OF RESULTS AND CONCLUSIONS

Relation of Atmospheric Humidity to Development of Cantaloupe Powdery Mildew.—The unusual occurrence of a prolonged period of cloudy or humid weather just preceding the maturity of the canta-

Fig. 13.—Brush and paper windbreaks as used in early cantaloupe fields to prevent the wind from whipping off the crown set blossoms.

loupe crops of 1925 and 1926 probably accounts for the widespread attacks of powdery mildew which swept over the Imperial Valley during those years. Once the disease becomes well established and generally distributed in the fields, local conditions of atmospheric humidity are perhaps of more importance in its spread than are the general climatic conditions of the region as a whole. Within a given field any of a number of factors may contribute to maintain a condition of high relative atmospheric humidity favorable to the disease. Too frequent irrigation of fields, or poor surface drainage, may keep the soil surface under the vines wet for several days following each application of water. The air around the plants is prob-

ably also maintained at a high level of humidity during most of this time. If the brush and paper windbreaks (fig. 13) used in the early fields are placed around and over the hills as they are in squash plantings, the soil and plants are shaded and protected from the drying action of air currents or winds. It seems evident from observation and experiments that such conditions favor the development of the fungus.

Host Plants Upon Which the Mildew Fungus Overwinters.—Neither of the two wild host plants upon which the fungus was thought to overwinter appear to be important. In fact, the failure of all attempts to inoculate cantaloupe plants with the powdery mildew fungus which attacks the common wild sunflower or to infect this sunflower with the cantaloupe mildew fungus strongly suggests that these two pathogenes are distinct physiologic races. The common wild gourd of the region shows marked resistance to the disease even when surrounded by heavily infected cantaloupe plants. Small, greenish-yellow spots appear on the leaves but the fungus in these spots does not thrive or sporulate freely. Growing under dry, desert conditions this plant is probably almost entirely resistant to infection. Winter grown cucurbits and volunteer melon plants are the two principal plants on which the fungus overwinters. Volunteer melon plants are of lesser importance as frosts during the winter are usually of sufficient severity to kill all but a very few which chance to be growing in protected spots. The widely distributed, small plantings of winter squash, however, are grown under the protection of brush and paper shelters and hence often survive frosts which might kill unprotected plants. From a few infected plants, the disease spreads through the entire planting, slowly at first, but more rapidly as the season advances and higher temperatures favor spore germination and growth of the fungus. Thus, these squash patches become centers of heavy infection from which spores may be carried by the wind to nearby cantaloupe fields. These become diseased and, in turn, become a source of infection for other fields.

Control Experiments with Sulfur Fungicides.—The experiments with sulfur dusts or sprays have demonstrated that they cause severe injury to the plants if applied to cantaloupe vines in the Imperial Valley after the middle of April. After that time the daily temperatures frequently range from a minimum of 60° F or above to a maximum of 95° or above. From the results of his experimental work on control measures for apple powdery mildew in the arid regions of the Pacific Northwest, Fisher[14] stated that sulfur injury

invariably followed the application of sulfur in any form in the hot districts when shade temperatures of 90° F or more are experienced within two weeks of the time of spraying. Sanders[33] found that there was danger of any sulfur compound burning the fruit and foliage of apple trees if the temperature remains above 90° F for any considerable period following its application. In our trials, applications of sulfur dusts and sprays made before the middle of April were less injurious than the later ones. Not only were the maximum temperatures lower then, but, at that time the vines were also smaller, had less total leaf area, and had fewer mature leaves than those which were dusted or sprayed later. The quantity of sulfur applied to the leaves and the temperatures prevailing immediately following its application appear to be the most important factors which determine the degree of resultant injury.

All grades of sulfur used in the dusting experiments proved to be equally toxic. Mixing them with lime, gypsum, or infusorial earth did not reduce their toxicity to any appreciable extent. The materials served apparently only as inert carriers, for when applied alone as dusts they were neither fungicidal nor injurious.

No evidence that the application of sulfur to the surface of the soil gave effective control of mildew was found during the course of these experiments. Mildew spots normal in appearance with the fungus sporulating freely have often been observed on leaves directly over and within a few inches of the small piles of sulfur on the soil. Vogt[37] and Tucker[36] have shown that sulfur does sublime at the higher air temperatures (25° to 50° C) but the rate of sublimation is so slow and the quantity sublimed so small that under field conditions it would seem that the so-called "fuming" of the sulfur distributed on the ground could not be relied upon to give effective control of the disease. The value of such treatments must therefore depend to a large degree, upon the fungicidal action of the small amount of sulfur which is lifted from the soil and 'dusted' on the plant surfaces by air currents or winds. In the absence of winds or in fields protected by windbreaks or brush very little of the sulfur placed on the soil would be carried to the cantaloupe vines. From the results of the 1927 experiments, it is obvious that enough may be lifted from the soil when the field is exposed to frequent strong winds to cause severe damage to the plants. Applications of more than 30 pounds of sulfur per acre sifted around the hill or more than 60 pounds per acre distributed on the soil in small piles burned the plants severely. Comparison of these results with those of 1926 and

1928 indicates that sulfur is injurious only when brought in contact with the foliage by wind or other means and that the degree of injury which results is proportional to the actual amount of sulfur which the plant receives.

Cucurbit species vary in their susceptibility to the so-called "sulfur burn." Field trials have shown that squash varieties are highly resistant to sulfur injury. It was found that frequent dusting of squash plants effectively controlled mildew without injurious effects resulting. This agrees with Guerrero's report[16] that squash plants were not affected by sulfur-dust applications although muskmelon vines were killed by the same treatment. Individual plants of cantaloupe and other commercial melon varieties have displayed a marked resistance to sulfur burn. Selections of these are now being grown and will be tested in field trials.

Experiments with Copper Fungicides.—Dry copper dusts do not effectively control powdery mildew under conditions prevailing in Imperial Valley during the latter half of the cantaloupe growing season. Rains or dews rarely occure between the middle of April and the end of the harvest in July. To be actively fungicidal some of the copper salt must go into solution in free water on the plant foliage. The absence of rains or heavy dews therefore probably accounts for the failure of these materials to control the disease.

Of the liquid sprays, three applications of bordeaux mixture 3–3–50 and 4–4–50 at two-week intervals gave the best results. These, however, gave only partial control. Although a particular effort was made to spray the plants thoroughly, the under sides of many leaves were found to have not been wet. The sprays applied to the vines dried rapidly, hence their fungicidal activity was probably of short duration and confined to the mildew spores and hyphae of the fungus with which they came in direct contact at the time of their application. As the fungus can develop on the foliage in the absence of free water which is essential to copper activity, the presence of dried copper spray membranes on the leaves probably offers little or no protection against subsequent infection. None of the copper sprays or dusts injured the plants to which they were applied. Late applications of oil spray injured the vines and had no evident fungicidal effect.

Fertilizer Applications.—Neither complete commercial fertilizer nor any of its constituents applied in amounts equivalent to a 750-pound per acre application of 4–8–5 commercial mixture gave any evidencing of influencing the susceptibility of the plants to this disease. Sulfur drilled into the soil had no apparent influence on the susceptibility or resistance of cantaloupe plants to powdery mildew.

SUMMARY

As soon as the crops are harvested from fields of cantaloupes, squash, cucumbers and other susceptible plants the vines should be plowed under, and these fields, as well as ditch banks, waste areas and land near field packing sheds, should thereafter be kept clear of volunteer vines.

Thorough dusting of squash fields will keep them practically free of mildew. Dusting should begin before the disease appears and should be repeated several times before the crop is harvested. Applications of 10 to 15 pounds of finely ground or sublimed sulfur per acre should be made at two-week intervals.

Very small quantities of sulfur applied as dusts or sprays caused too severe injury to be recommended for use on commercial cantaloupe varieties grown under Imperial Valley conditions.

Dry copper dusts proved fungicidally inactive and hence of no value in controlling powdery mildew. Bordeaux sprays gave only partial control. Other liquid sprays applied proved to be either injurious or ineffective.

Application of sulfur to the surface of the soil as a control measure for the disease has been tried extensively. Positive evidence of mildew control by this means is lacking. Field trials have shown that severe sulfur injury may result from heavy applications made during periods of strong prevailing winds of common occurrence in March, April, and May.

One year's trial of sulfur and of inorganic fertilizers drilled into the soil gave no evidence that these materials influenced the susceptibility or resistance of cantaloupe plants to the disease.

Too frequent or excessive irrigation of heavy soils or those having poor surface or sub-surface drainage should be avoided. Less frequent or lighter applications of water will supply sufficient moisture to the plants and will allow the soil surface to dry between irrigations.

Brush and paper windbreaks, if used, should be placed near the ridge of the cantaloupe beds and should be removed as soon as the 'crown set' melons are well developed.

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